MAJOR RESEARCH PROJECT: FINAL REPORT

Title: Effect of Plant Extracts on the Growth and Productivity of Silkworm, *Bombyx mori* L.

SUBMITTED TO

UNIVERSITY GRANTS COMMISSION

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UNIVERSITY GRANTS COMMISSION MAJOR RESEARCH PROJECT

Final Report of The Work Done on The Project

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Name of the principal investigator**: Prof. S. Ramakrishna**

Title of the Project: **"Effect of Plant Extracts on the Growth and Productivity of Silkworm, *Bombyx mori* L."**.

INTRODUCTION AND REVIEW OF LITERATURE

Silk, an animal fiber produced by silkworm, is considered as the undisputed queen of textiles. Silkworm rearing gives reaps in thirty days, thereby enhancing employment and helping in inclusive agro-industry development. India is world second largest producer of silk next to China.

India is a unique country in producing all four varieties of commercial silks of Mulberry, Eri, Tasar and Muga. Among mentioned silks, mulberry silk accounts for the highest share among total silk production. Mulberry raw silk production in India, has registered a growth rate of 8.81 percent. However, demand for silk is growing at the rate above production, i.e., 10 per cent. The deficit of silk production is filled by imports, mainly from China to satisfy the present need of the weaving industry. Karnataka state dominates the national scenario by contributing nearly 65 per cent to the total raw silk produced in India (Anonymous 2013). Moreover, low silk productivity coupled with inferior quality of the silk is seen in India. Considering strong growing domestic market and expanding export market. It can be projected that the demand for quality and quantity of raw silk would be huge in the years to come.

Chemicalization of mulberry sericulture is inevitable to full fill the fabric demand. In long run account of soil ill-health may reduce quality of mulberry leaves production. Leaves quality and quantity influence growth and development of silkworms in turn quality and quantity of cocoon and raw silk produced. Miyashita and Singhal, Mala et al. opined that several factors *viz.,* mulberry leaf (38.20%), climate (37.00%), rearing technique (9.30%), silkworm race (4.20%), silkworm eggs (3.10%) and other factors (6.60%) are known to influence successful cocoon production in various degrees. In sustaining sericulture industry with more hybrid varieties of mulberry and silkworm varieties have to be improved.

Reports indicate role of botanicals supplementation to mulberry leaves lowers bottlenecks in quality and quantity of raw silk production. Administration of botanicals to mulberry leaves supplements various biochemical constituents (Amino acid, proteins, alkaloids, glucoside, phyllanthine, psoralen, betasitosterol) in addition protrays phago stimulation. Healthy growth of silkworm depends largely on nutritional status of leaves fed to silkworms (Krishnaswami, 1971; Ravikumar 1988). Botanical supplementation extracts of leaf, flower and pod phytochemicals have played role in improvement of larval growth and cocoon weight (Bin, Su et al. 2010; Matsura 1994; Ito and Niminura 1966a; Horie, Watanable et al. 1967; Vishwanath and Krishnamurthy 1982; Subburathinam and Krishnan 1998).

Aqueous extracts of *Lantana camara, Parthenium hysterophorus* and *Tridax procumbens* (Hipparagi *et al.,* 2001); *Tribulus terrestris* (Murugesh and Mahalingam, *2005); P. hysterophorus* (Patil, R et al. 2005) *P. hysteron phorus* and *Tridax procumbens, Psoralea coryleifolia* and *Phyllanthus niruri* (Shubha 2005) and with an *insomnifera* have improved the growth and development of silkworm, *B. mori,* leading to better economic gains (Bhaskar, Sridevi et al. 2004; MAHESHA 1999 Mahesha *et al.,* 1999b). Leaf extracts of *Adhatoda vasica*, *Phyllanthus niruri* and *Psorealia coryeliafolia* on administration to silkworm, exhibited high cocoon production (Prajapathi, S et al. 2003). The effect of plants extract have shown significant improvement in cocoon weight, pupal weight and shell weight (Maribashetty, Gayathri et al. 2010; Murugesh and Bhaskar 2007;Gayathri 2005; Murugan, Jeyabalan et al. 1999; Lakshmanan 2007; Shashidhar, T et al. 2009). Hence, *Adhatoda vasica* (Acanthaceae), *Phyllanthus niruri* (Euphorbiaceae) and *Terminalia arjuna* (Combrataceae) (Shubha 2005), were selected for the present study.

In this context vastly cultivated V1 mulberry variety and common botanical extracts were used to affect growth and development of mulberry silkworm PM, CSR2 and PMXCSR2 and its effects on cocoon productivity were investigated. The cocoons formed by silkworm PM, CSR2 and PMXCSR2 in combination with fortified V1 mulberry variety were analyzed for various parameters of larval to cocoon formation of silkworm. The cocoon features and silk characters on commercial scale of *B. mori* (PM, CSR2 and PM×CSR2) were tested along with two controls (Kumari, Bhaskar et al. 2010 ; Shubha, Bhaskar et al. 2007; Bhaskar, G et al. 2004; Hipparagi, Rayar et al. 2001; Murugesh and Mahalingam 2005).

The facts of previous literature allured to attempt in exploring effectiveness of using botanical extracts for producing silk in high quality and quantity. The plant extracts are cheaper, non-polluting, non-toxic besides easier to apply and digest, serve as alternative to hybrid improvement in production of silk. The facts allured to attempt in exploring effectiveness of using botanical extracts for producing silk in high quality and quantity. The activity of aqueous extracts of selected five plant species were checked on yield of silkworm. The supplemented botanical extracts have positive effect on quality and quantity of cocoon and its silk formation were shown by conducting experiments. Further investigations are necessary in quantifying the amount of leaf extracts to be supplemented for higher production of cocoon.

OBJECTIVES

The study was undertaken with following objectives

a. Effect of plant extracts on consumption indices in silkworm.

b. Effect of plant extracts on metric parameters of silkworm.

c. Field evaluation of effective plant extracts at farmers rearing houses.

METHODOLOGY

Studies conducted on widely used Silkworm Breeds/Hybrids *viz.,* PM, CSR_2 and PM×CSR_2 of IV and V instars, feeding them on common V1 mulberry variety. The aqueous extract of supplements *Adathoda vasica, Bougainvillea spectabilis, Phyllanthus niruri, Terminalia arjuna,* and *Pongamia glabra* applied on V1 mulberry leaves (known dimensions and weight) for testing silkworm feeding, digestion and productivity.

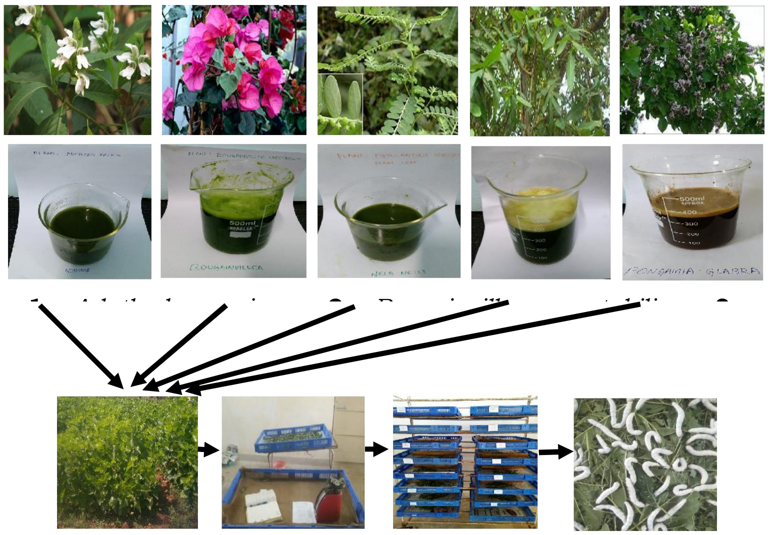
Sl. No	Plants Species Name	Family Name	Plant Common Name
1	*Adathoda vasica*	Acanthaceae	Adusoge
2	*Bougainvillea spectabilis*	Nyctaginaceae	Bougainvillea
3	*Phyllanthus niruri*	Euphorbiaceae	Kirunelli
4	*Terminalia arjuna*	Combretaceae	Arjuna
5	*Pongamia glabra*	Leguminaceae	Honge

a. Field cultivation of mulberry and fortifying botanicals

The V1 Mulberry variety cultivated for fresh procurement, on land spacing 2 x 3 feet in Department of Zoology, Bangalore University, Bengaluru. Standard growing practices followed with periodical application of farmyard manure, minimal chemical fertilizer and Irrigated on weekly basis. *Adathoda vasica, Bougainvillea spectabilis, Phyllanthus niruri, Terminalia arjuna,* and *Pongamia glabra* grown in Department of Zoology, Bangalore University, Bengaluru for fresh procurement and preparation of extracts.

The fumigation of laboratory and chemical disinfestation by chlorofect liquid for disinfecting rearing rooms and rearing equipment were carried out each time prior to rearing. Pest meddling during rearing of silkworm was abridged in rooms by meshing of doors and windows (Krishnaswami*et al.*, 1973).

Fig 1:



The 3rd instar larvae of PM, CSR_2 and $PMxCSR_2$ were obtained from Karnataka State Sericulture Research and Development Institute (KSSRDI), Thalaghattapura, Bengaluru. Larvae reared under standard conditions of 25±2°C, 75±5% relative humidity maintained (Krishnaswami, 1986). Non-fortified Mulberry leaves were fed up to 4th moult, there after selected plants extract supplemented on mulberry leaves to feed. The observations were made and results are tabulated below.

b. Collection and preparation of plant extracts:

The plants for supplementation *viz., Adathoda vasica*, *Pongamia glabra*, *Bougainvillea spectabilis*, *Phyllanthus niruri,* and *Terminalia arjuna* were cultivated in the Department of Zoology as per the methods of (Rai *et al.*, 2006; Kumari *et al.*, 2010; G. P. Singh *et al.*, 2010; Latha, R et al. 2012; Subramanianan *et al.*, 2013 and Mala 2014). The leaves were freshly collected as per experimental requirement from each plant, washed using running tap water, rinsed with distilled water and shade dried.

The aqueous extracts of selected plants were prepared by using electrical mixer with addition of plant leaves and distilled water in weight by volume 1:1 ratio. The stock solution of extracts obtained by method of double filtration of grinded solution, using double layer sterile muslin cloth and Whatman's filter paper respectively. The collected extracts stock solution refrigerated and replaced on fortnight basis regularly. From this stock solution 1.5ml, 2.0ml and 2.5ml were added to 10ml distilled water to obtain the required concentrations (Patil *et al.*, 1997; and Mane 1998).

c. Feeding method:

Silkworm of IV and Vth instars was reared using V1 mulberry fortified leaves (5 selected plant extracts). The control and treated silkworms were reared in similar concentrations of 0.15ml, 0.2ml and 0.25ml concentration of plant extracts. Silkworm larvae of 50 larvae of each PM, CSR_2 and PM x CSR_2 were taken per batch and repetitive process of feeding was continued. Cleaned V1 mulberry leaves were cut into standard size bits of 10×12 cm and sprayed with 0.15ml, 0.2ml and 0.25ml botanical extracts on both sides of mulberry leaves and shade dried for ten minutes later fed to silkworms.

I. Effect of plant extracts on consumption in silkworm

Effect of plant extracts on consumption indices were studied on IV and V instar silkworm larvae of races PM, CSR_2 and PM x CSR_2. The following parameters *viz.,* Consumption, Digestion, Consumption index, Growth rate, Efficacy of conversion of ingested food, Efficacy of conversion of digested food, Approximate digestibility, Reference ratio as were noted (Waldbauer 1964).

II. Effect of plant extracts on metric parameters of silkworm.

The fortified mulberry leaves feeding to Silkworm larvae races PM, CSR_2 and PM x CSR_2 on fourth (second day first feed) and fifth instar (every day of first feed) were opted (according to), in remaining period unfortified mulberry leaves were fed. The larvae to pupa (ripened) formation was allowed on bamboo mountage for cocoon spinning. The cocoons were harvested after 5th day of mounting. The yield parameters *viz.,* larval duration, cocoon weight, shell weight, pupal weight, shell ratio, and silk characters like filament length, weight and denier were recorded and analyzed in control and the experimental silkworms.

III. Field evaluation of effective plant extracts at farmers rearing houses

The highest yield giving effective plant extracts on silkworm races of PM, CSR_2 and PM x CSR_2 were evaluated at farmers' field in largescale. The yield parameters *viz.,* larval duration, cocoon weight, shell weight, pupal weight, shell ratio, and silk characters like filament length, weight and denier were recorded and analyzed in field.

d. Statistical analysis

Results analyzed and presented as means ± SD, P values< 0.05 were regarded as statistically significant.

RESULTS

I. Effect of plant extracts on consumption in silkworm

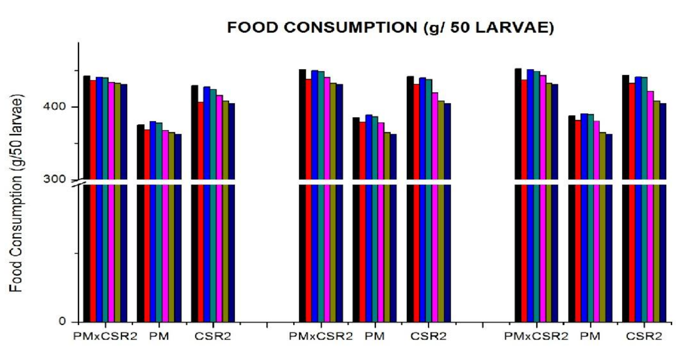
A. Food consumption (g)

The quantity of food intake indicates the food preference by Silkworm. The food preference in turn governed by the biological and physiological properties of mulberry leaves. The fifth instar larvae fed with mulberry leaves treated with *A. vasica*> *P. niruri*> *T arjuna*> *B. spectabilis*> *P. glabra* leaf extracts registered significantly higher consumption. The lowest consumption was recorded in normal control of fifth instar larvae for all five days except on second and fifth day because the plant extracts *B. spectabilis* and *P. glabra* registered lower consumption compared to normal control.

There exists a variation in consumption among other treatments for different days tested. This could be assumed that the leaf extracts containing the olfactory attractants and the biting factors such as triterpenes, sterols like stigmasterol, sitosterol, campesterol etc. and these components might have influenced the larvae consuming more leaf during fifth instar. The food consumption was increased from day to day and there was a steep increase on fifth day.

Table 1 and Graph 1. Effect of selected plant extracts on food consumption (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

Plant Extracts	FOOD CONSUMPTION (g/50 larvae)								
	1.5 Conc.			2.0 Conc.			2.5 Conc.		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	442.54	375.06	429.34	451.36	385.42	442.23	452.26	387.67	443.73
B spectabilis	436.43	368.43	406.49	438.21	379.37	430.98	437.11	381.67	432.28
P niruri	440.87	379.98	427.27	449.98	388.98	439.85	451.38	390.38	441.65
T arjuna	439.94	377.88	424.22	448.51	386.86	437.28	449.21	389.6	440.5
P glabra	433.42	367.56	415.66	440.28	378.32	419.74	442.86	380.82	421.4
Water Control	432.62	364.75	407.85	432.62	364.75	407.85	432.62	364.75	407.85
Control	430.32	362.72	404.5	430.32	362.72	404.5	430.32	362.72	404.5



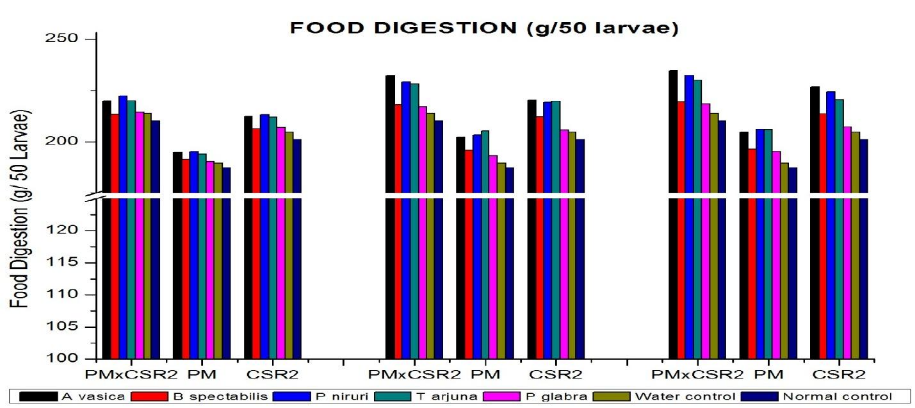
B. Food digestion (g/50 larvae)

The amount of food digested indicated the amount of nutrient passed through the digestive system for utilization.

Treatments were given during first, second, third, fourth and fifth day. *A. vasica*> *P. niruri*> *T arjuna*> *B. spectabilis*> *P. glabra* recorded significantly higher digestion at 1.5, 2.0 and 2.5 percent concentration. The lower digestion was noticed in *P. glabra*. The water and normal control did not differ significantly. This may be due to digestibility of the chemical compounds present in the respective plants.

Table 2 and Graph 2. Effect of selected plant extracts on food digestion (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

Plant Extracts	FOOD DIGESTION (g/50 larvae)								
	1.5 Conc.			2.0 Conc.			2.5 Conc.		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	219.98	194.96	212.44	232.19	202.43	220.32	234.54	204.67	226.76
B spectabilis	213.36	191.48	206.39	218.11	195.85	212.18	219.46	196.54	213.63
P niruri	222.44	195.33	213.12	229.26	203.32	219.35	232.34	205.98	224.33
T arjuna	220	194.12	211.93	228.2	205.33	219.78	230.12	205.89	220.45
P glabra	214.44	190.39	206.86	217.06	193.21	205.78	218.4	195.22	207.33
Water Control	213.92	189.54	204.7	213.92	189.54	204.7	213.92	189.54	204.7
Control	210.23	187.43	201.23	210.23	187.43	201.23	210.23	187.43	201.23

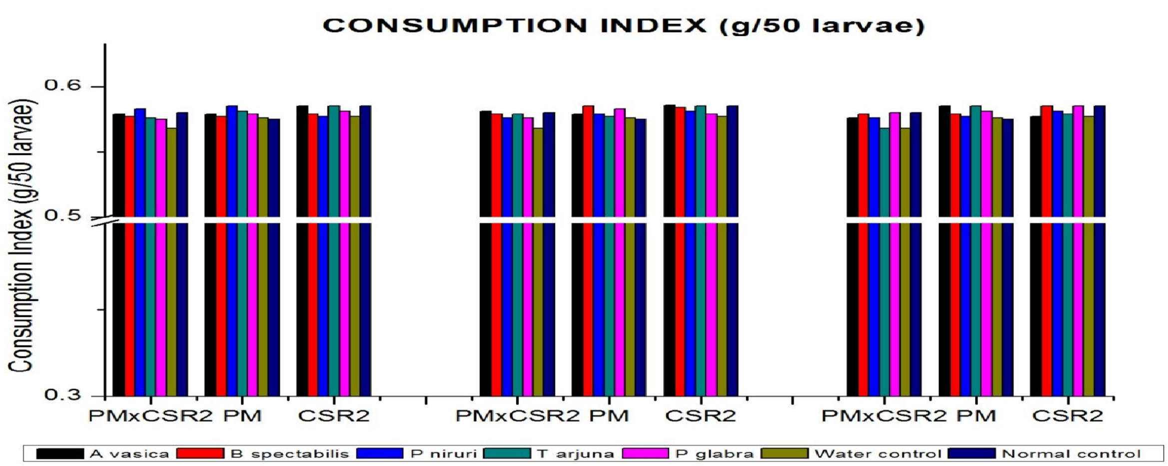


C. Consumption index

Consumption index is consumption per mean larval weight per day, it measures the rate at which food enters the digestive system. Plant extracts were supplemented and treated with leaves of *A. vasica, P. niruri, T arjuna, B. spectabilis* and *P. glabra.* The extracts showed varied degree of consumption on fifth instar larvae with significantly higher CI. The Water control and normal control was found to be lower in all cases.

Table 3 and Graph 3. Effect of selected plant extracts on Consumption Index (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

PLANT EXTRACTS	CONSUMPTION INDEX (g/50 larvae)								
	1.5 Conc.			2.0 Conc.			2.5 Conc.		
	PM x CSR	PM	CSR2	PM x CSR	PM	CSR2	PM x CSI	PM	CSR2
A vasica	0.579	0.579	0.585	0.581	0.579	0.586	0.576	0.585	0.577
B spectabili	0.577	0.577	0.579	0.579	0.585	0.584	0.579	0.579	0.585
P niruri	0.583	0.585	0.577	0.576	0.579	0.581	0.576	0.577	0.581
T arjuna	0.576	0.581	0.585	0.579	0.577	0.585	0.568	0.585	0.579
P glabra	0.575	0.579	0.581	0.576	0.583	0.579	0.58	0.581	0.585
Water Contr	0.568	0.576	0.577	0.568	0.576	0.577	0.568	0.576	0.577
Control	0.58	0.575	0.585	0.58	0.575	0.585	0.58	0.575	0.585



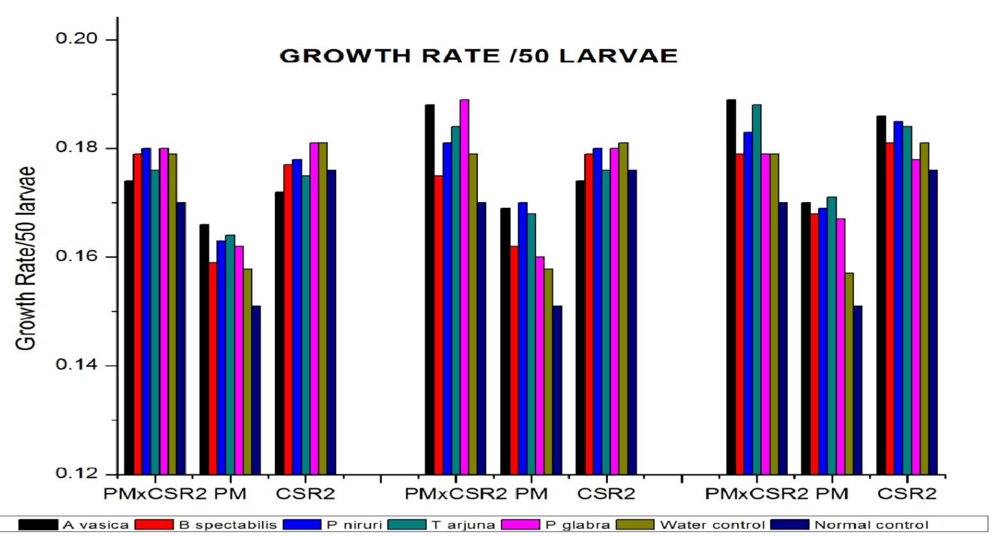
D. Growth rate

Growth rate (OR) explains how much weight is gained per day per gram of mean body weight during the larval stage. This depends on quality of host or physiological state of larvae.

Plant extracts were supplemented and treated with leaves of *A. vasica, P. niruri, T arjuna, B. spectabilis* and *P. glabra.* The extracts showed varied degree of consumption on fifth instar larvae from first day to the spinning. Significantly higher CI in growth rate was noticed after treatment with leaf extracts compared to water and normal control.

Table 4 and Graph 4. Effect of selected plant extracts on Growth Rate (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

PLANT EXTRACTS	GROWTH RATE (g/50 larvae)								
	1.5 Conc.			2.0 Conc.			2.5 Conc.		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	0.174	0.166	0.172	0.188	0.169	0.174	0.189	170	0.186
B spectabilis	0.179	0.159	0.177	0.175	0.162	0.179	0.179	0.168	0.181
P niruri	0.18	0.163	0.178	0.181	0.17	0.18	0.183	0.169	0.185
T arjuna	0.176	0.164	0.175	0.184	0.168	0.176	0.188	0.171	0.184
P glabra	0.18	0.162	0.181	0.189	0.16	0.18	0.179	0.167	0.178
Water Control	0.179	0.1578	0.181	0.179	0.1578	0.181	0.179	0.1578	0.181
Control	0.17	0.151	0.176	0.17	0.151	0.176	0.17	0.151	0.176



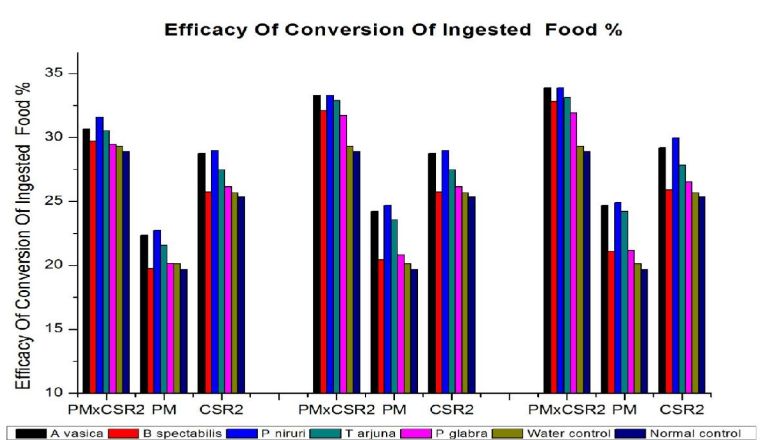
E. Efficiency of Ingested Food (%)

The quantity of food intake indicates the food preference by Silkworm. The food preference in turn governed by the biological and physiological properties of mulberry leaves. The fifth instar larvae fed with mulberry leaves treated with *P. niruri*> *T arjuna* > *A. vasica*> *B. spectabilis*> *P. glabra* leaf extracts registered significantly higher consumption. The lowest consumption was recorded in normal control of fifth instar larvae for all five days except on second and fifth day because the plant extracts *B. spectabilis* and *P. glabra* registered lower consumption compared to normal control.

There exists a variation in consumption among other treatments for different days tested. This could be assumed that the leaf extracts containing the olfactory attractants and the biting factors such as triterpenes, sterols like stigmasterol, sitosterol, campesterol etc. and these components might have influenced the larvae consuming more leaf during fifth instar. The food consumption was increased from day to day and there was a steep increase on fifth day.

Table 5 and Graph 5. Effect of selected plant extracts on Efficacy of Conversion of Ingested Food percentage (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

PLANT EXTRACTS	**Efficacy Of Conversion Of Ingested Food %**								
	1.5 Conc.			**2.0 Conc.**			**2.5 Conc.**		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	30.64	22.34	28.76	33.29	24.2	28.76	33.89	24.72	29.22
B spectabilis	29.72	19.73	25.72	32.1	20.43	25.72	32.82	21.1	25.9
P niruri	31.6	22.72	28.98	33.29	24.72	28.98	33.9	24.9	29.98
T arjuna	30.52	21.56	27.48	32.86	23.56	27.48	33.13	24.22	27.83
P glabra	29.44	20.14	26.13	31.71	20.8	26.13	31.91	21.15	26.52
Water Control	29.31	20.12	25.67	29.31	20.12	25.67	29.31	20.12	25.67
Control	28.88	19.67	25.34	28.88	19.67	25.34	28.88	19.67	25.34



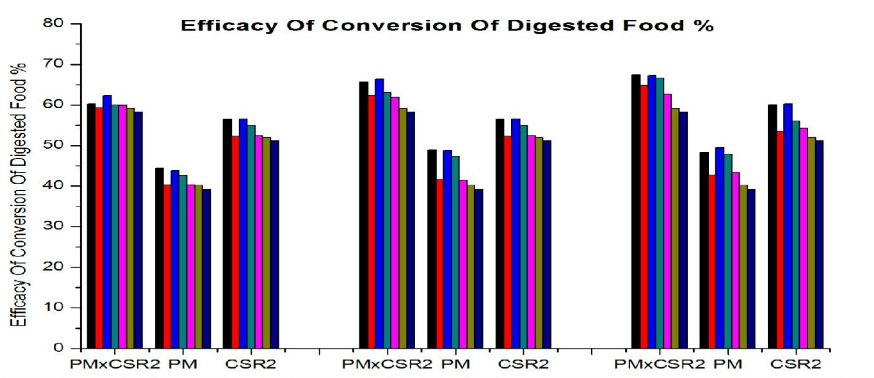
F. Efficiency of conversion of Digested Food (%)

The quantity of food intake indicates the food preference by Silkworm. The food preference in turn governed by the biological and physiological properties of mulberry leaves. The fifth instar larvae fed with mulberry leaves treated with *P. niruri*> *A. vasica*> *T arjuna*> *P. glabra* > *B. spectabilis* leaf extracts registered significantly higher consumption. The lowest consumption was recorded in normal control of fifth instar larvae for all five days except on second and fifth day because the plant extracts *P. glabra* and *B. spectabilis* registered lower consumption compared to normal control.

There exists a variation in consumption among other treatments for different days tested. This could be assumed that the leaf extracts containing the olfactory attractants and the biting factors such as triterpenes, sterols like stigmasterol, sitosterol, campesterol etc. and these components might have influenced the larvae consuming more leaf during fifth instar. The food consumption was increased from day to day and there was a steep increase on fifth day.

Table 6 and Graph 6. Effect of selected plant extracts on Efficacy of Conversion of Digested Food percentage (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

PLANT EXTRACTS	**Efficacy Of Conversion Of Digested Food %**								
	1.5 Conc.			**2.0 Conc.**			**2.5 Conc.**		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	60.25	24.47	56.48	65.65	48.87	56.48	67.5	48.27	60.12
B spectabilis	59.34	40.22	52.3	62.34	41.58	52.3	64.84	42.68	53.55
P niruri	62.34	43.86	56.61	66.34	48.75	56.61	67.3	49.5	60.31
T arjuna	60.04	42.6	54.91	63.04	47.34	54.91	66.64	87.84	56.1
P glabra	59.96	40.29	52.44	61.96	41.44	52.44	62.63	43.36	54.24
Water Control	59.09	40.21	51.96	59.09	40.21	51.96	59.09	40.21	51.96
Control	58.26	39.12	51.19	58.26	39.12	51.19	58.26	39.12	51.19



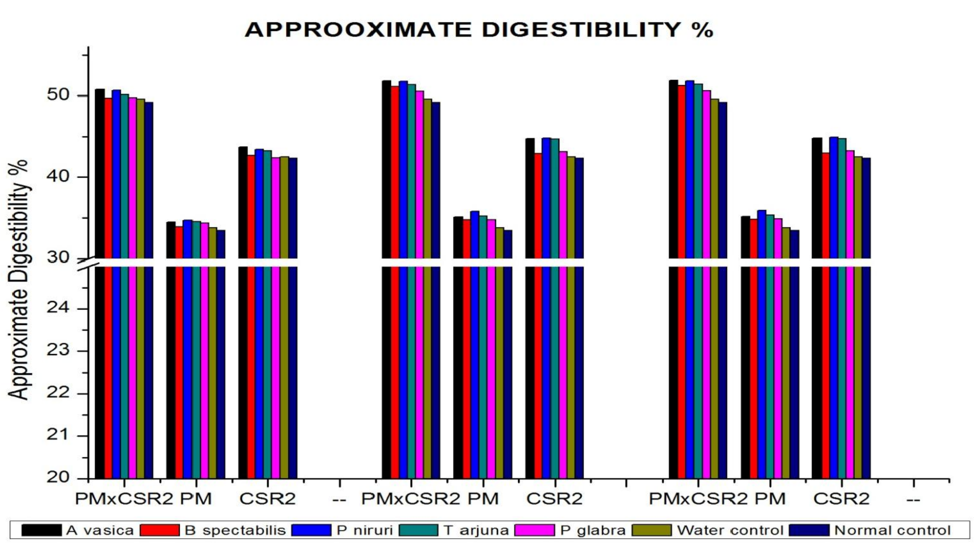
G. Approximate digestibility (%)

Approximate digestibility (AD) is a precise measurements of digestibility to evaluate the amount of food digested. It measures the digestible portion of food that is ingested (Basaiah, 1988).

The quantity of food intake indicates the food preference by Silkworm. The food preference in turn governed by the biological and physiological properties of mulberry leaves. The fifth instar larvae fed with mulberry leaves treated with *A. vasica*> *P. niruri*> *T arjuna* > *B. spectabilis*> *P. glabra* leaf extracts registered significantly higher consumption. The lowest consumption was recorded in normal control of fifth instar larvae for all five days except on second and fifth day because the plant extracts *P. glabra* and *B. spectabilis* registered lower consumption compared to normal control.

Table 7 and Graph 7. Effect of selected plant extracts on Efficacy of Conversion of Digested Food percentage (g/50 larvae) in fifth instar larvae of *Bombyx mori* L.

PLANT EXTRACTS	Approximate Digestibility %								
	1.5 Conc.			2.0 Conc.			2.5 Conc.		
	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2	PM x CSR2	PM	CSR2
A vasica	50.79	34.5	43.73	51.85	35.15	44.73	51.91	35.22	44.81
B spectabilis	49.75	33.9	42.69	51.14	34.79	42.89	51.22	34.86	42.98
P niruri	50.67	34.72	43.4	51.79	35.82	44.84	51.82	35.94	44.95
T arjuna	50.16	34.57	43.27	51.37	35.27	44.67	51.42	35.34	44.75
P glabra	49.82	34.38	42.4	50.57	34.8	43.14	50.6	34.89	43.24
Water Control	49.65	33.82	42.48	49.65	33.82	42.48	49.65	33.82	42.48
Control	49.24	33.43	42.3	49.24	33.43	42.3	49.24	33.43	42.3



II. Effect of plant extracts on metric parameters of silkworm.

The experimental data of “Selected botanical extracts on productivity of 4th and 5th instar silkworm larvae” in diverse rearing parameters were found to be significant. The 3rd instar larvae obtained from KSSRDI observed to grow well in laboratory conditions.
B. mori races PM, CSR2 and PMXCSR2 of larvae 4th and 5th instars were fed with 0.15ml, 0.2ml and 0.25ml of *Adathoda vasica, Bougainvillea spectabilis, Terminalia arjuna, Phyllanthus niruri* and *Pongamia glabra* extracts. These botanical extracts on comparing with normal control and water control showed increase in cocoon weight, pupal weight, shell weight, Cocoon shell ratio, number of cocoons per liter, Cocoon size and breadth, Pupal weight, Cocoon yield in number, Cocoon yield in weight, Shell thickness, Filament length and breadth and Denier. The effect was intense with respect to cocoon parameters in in-vitro conditions.

A. Single Cocoon Weight (g):

Among five tested botanicals *A. vasica, P. niruri* and *T. arjuna* increased cocoon weight of silkworm races PM, CSR2 and PMXCSR2 at varied degrees. The increased cocoon weight ratio of silkworm races after experimentation were as follows PMXCSR2>CSR2>PM. Among races PMXCSR2 showed progressive increase in cocoon weight on treatment with increased dosage of *A. vasica>T. arjuna> P. niruri* botanicals. CSR2 race cocoon weight increased respectively by botanicals of *P. niruri>A. vasica> T. arjuna*. PM race cocoon weight increase shown only with *A. vasica>P. niruri* botanicals. The cocoon weight of races PM, CSR2 and PMXCSR2 with supplements summarized in Table8 and Graph8.

B. Single shell weight (g):

An increased shell weight of PM, CSR2 and PMXCSR2 races due to supplementation of *A. vasica, B. spectabilis, T. arjuna, P. niruri*and *P. glabra* botanicals ranged from 0.356 to 0.395 g. Degree of increased single shell weight obtained by races of PMXCSR2 >CSR2> PM were mentioned. PMXCSR2 race showed progressive increase in cocoon weight in comparison to control on treatment with *P. niruri>A. vasica>T. arjuna> B. spectabilis> P. glabra* botanicals respectively. CSR2 race cocoon weight has increased respectively on supplementing V1 mulberry with of *T. arjuna> P. niruri>A. vasica> B. spectabilis*. PM race increased cocoon weight shown only with *P. niruri> A. vasica>T. arjuna* botanicals respectively. The results of cocoon weight are summarized in Table 9 and Graph 9.

C. Cocoon shell ratio:

Cocoon shell ratio in proportion of shell weight to cocoon weight is expressed in percentage and computed with using formula: CSR (%) = SW(g)/CW(g)X100 [SW is shell weight in grams and CW is cocoon weight in grams]. Economic parameters were analyzed among control and the experimental silk worms. These results are in line with findings reported on cocoon shell ratio from different silkworms fed with extra-foliated mulberry leaves. The cocoon shell ratio of control treated silkworm was in range 15.03 to 16.32%. The cocoon shall ratio in treated groups was in range of 15.49% to 19.31% to about their increasing races of PMXCSR2 >CSR2> PM respectively. Silkworm race PMXCSR2 showed progressive increase in percentage of cocoon shell ratio on botanical extracts of *P. niruri* and *B. spectabilis*. CSR2 race cocoon shell ratio percentage has increased respectively by botanicals of *T. arjuna*> *P. niruri*>*A. vasica*> *B. spectabilis*. PM race increased cocoon shell ratio shown only with *P. niruri* and *T. arjuna* botanicals. A significant difference was observed among the various doses of botanicals on silkworm breed with respect to shell ratios are summarized in Table.10 and Graph.10 below.

D. Number of cocoons per liter:

Increase in cocoon number per liter will reduce weight of cocoons and yield of silk. The cocoon number per liter exhibits good silk yield of races. The efficiency of silkworm races on feeding with botanically fortified mulberry yielded cocoons that were lower in number per liter. The number of cocoons for different races are mentioned in descending order, PM (122-109/liter)>CSR2 (90-81/liter)> PMXCSR2 (97-81/liter). The different proportion of cocoon numbers yielded by silkworm races on feeding with fortified botanicals mentioned according to ascending order of cocoons obtained per liter. PM (*B.* spectabilis>P. *glabra*> *A. vasica*> *T. arjuna*> *P. niruri*), CSR2 (*B.* spectabilis>P. *glabra*> *A. vasica*> *T. arjuna*> *P. niruri*) and PMXCSR2 (P. *glabra*>*B.* spectabilis>*T. arjuna*> *A. vasica*>*P. niruri*) were in the ascending order of cocoons obtained per liter. A significant difference was observed among the various doses of botanicals on silkworm breed with respect to Number of cocoons per liter are summarized in Table 11and Graph11 below.

E. Cocoon size (Length X Breadth):

Increase in cocoon length and breadth will yield silk of export variety. The efficiency of silkworm races on feeding with botanically fortified mulberry yields cocoons with increased length and breadth. The length and breadth of cocoons for different races are mentioned in ascending order length PM (3.50-3.88)> CSR2 (3.23- 3.57)> PMXCSR2 (3.08-3.43) and breadth CSR2 (2.14- 2.43)> PMXCSR2(1.92-2.28)>PM (1.73-2.07). The difference in length and breadth will be fruitful in augmenting races for different proportions. The values for fortified botanicals in length were mentioned in ascending order of races, PM (*B.* spectabilis>P. *glabra*> *A. vasica*> *P. niruri*> *T. arjuna*), CSR2 (P. *glabra*>*B.* spectabilis> *P. niruri*>*A. vasica*> *T. arjuna*) and PMXCSR2 (P. *glabra*> *P. niruri*>*A. vasica*>*B.* spectabilis>*T. arjuna).* The values for fortified botanicals in breadth is mentioned in ascending order of races CSR2 (*A. vasica*> *B.* spectabilis> P. *glabra*>*P. niruri*> *T. arjuna*), PMXCSR2 (*B.* spectabilis> P. *glabra*> *A. vasica*>*P. niruri*>*T. arjuna)* and PM (*B.* spectabilis> *T. arjuna*> *P. niruri*> P. *glabra*> *A. vasica*). A significant difference was observed among the various doses of botanicals on silkworm breed with respect to number of cocoons per liter summarized in Table and Graph 12 & 13 below.

F. Pupal Weight:

Supplementation of aqueous plant extracts resulted in enhancement of pupal weight of PMXCSR2 (1.60-1.69g)> CSR2 (1.58- 1.63g)> PM (1.03-1.05g). Botanical extracts showed lower or equivalent pupal weight on all experimented silkworm races in comparison to control silkworm. The lower pupal weight correlates with higher silk productivity as shown by PM (*T. arjuna*< *P. niruri*<P. *glabra*<*B.* spectabilis< *A. vasica*), CSR2 (*T. arjuna*<*P. niruri*<*B.* spectabilis<*A. vasica*<P. *glabra*) and PMXCSR2 (*B.* spectabilis<P. *glabra*<*P. niruri*<*T. arjuna*< *A. vasica).* The additive effect on pupal weight registered significant results. The results of pupal weights are summarized in Table.15 and Graph.15 below.

G. Cocoon yield/10,000 larvae (by number):

The cocoon yield by number per 10,000 larvae exhibited significant changes in each of silkworm genotype. The increasing trend in cocoon yield for 10,000 larvae were shown by races in descending order of PMXCSR2 >PM>CSR2 after being treated with botanicals. The effects on each race shown by different botanicals are as follows PMXCSR2 (*P. niruri*> *T. arjuna*>P. *glabra*> *A. vasica*> *B.* spectabilis), PM (*A. vasica*> *T. arjuna*> *P. niruri*> P. *glabra*>

B. spectabilis) and CSR2(*P. niruri*>P. *glabra*> *A. vasica*> *B.* spectabilis> *T. arjuna*). The increase in cocoon formation by larvae after application of botanicals was found to be high and significant, due to decreased incidence of larval mortality. The results of experimented races with botanicals are summarized in Table.16 and Graph.16 below.

H. Cocoon yield/10000 larvae (by weight):

The cocoon yield by weight per 10,000 larvae exhibited significant changes in each of silkworm race. The increasing trend in cocoon yield for 10,000 larvae was shown by races in descending order of PMXCSR2 > CSR2>PM after treated with botanicals. The effects on each race shown by different botanicals are as follows PMXCSR2 (*A. vasica*>*P. niruri*> *T. arjuna*> *P. glabra*>*B. spectabilis*), CSR2 (*P. niruri*> *A. vasica*>*P. glabra*> *T. arjuna*> *B. spectabilis*) and PM (*A. vasica*> *T. arjuna*> *P. niruri*>*B. spectabilis*>*P. glabra*). The increase in cocoon weight by larvae on application of botanicals found to be high and significant due to increase in the weight of cocoon shell. The results of experimented races with botanicals are summarized in Table.17 and Graph.17 below.

I. Shell thickness:

Shell thickness is a significant parameter accounting for high silk productivity. Increase or decrease in shell thickness will directly impact on produced cocoon silk quantity. The experimented races of silkworm showed varied degree in thickness during observation are mentioned in descending order as PMXCSR2 (0.36 - 0.47mm)> CSR2 (0.32-0.42mm)> PM (0.26-0.33mm). An increase in shell thickness due to additive effect of botanicals is good orientation for field application. The contributions to shell thickness shown by botanicals upon races are given in ascending order PMXCSR2 (*B. spectabilis*<*P. glabra*<*T. arjuna*<*P. niruri*<*A. vasica*)> CSR2 (*B. spectabilis*<*P. glabra*<*A. vasica* = *P. niruri* = *T. arjuna*)> PM (*P. glabra* = *B. spectabilis*<*A. vasica*= *T. arjuna*<*P. niruri*). The results of experimented races with botanicals are summarized in Table18 and Graph18 below.

J. Filament length (m):

The filament length significantly increased in each silkworm breed after extra foliated V1 mulberry leaves were fed to breeds. The single cocoon filament length registered longest on extra foliation to races of silkworm were in descending order of PMXCSR2 (719.67 – 829.0 m)> CSR2 (695.33 – 758.0m)> PM (489.0 - 552.0mm). An increase in filament length shown by botanicals for races are given in ascending order PMXCSR2 (*P. glabra*=*B. spectabilis*<*P. niruri*<*T. arjuna*<*A. vasica*)> CSR2 (*B. spectabilis*<*P. glabra*<*A. vasica* <*T. arjuna*<*P. niruri*)> PM (*B. spectabilis*<*P. glabra*<*A. vasica*<*P. niruri*<*T. arjuna*). The results of increased filament length on experimented races with botanicals are summarized in Table.19 and Graph.19 below.

K. Filament weight:

The filament weight increased augments tensile strength of silk fiber. A significant difference in filament weight was noticed between additive botanicals after administering to silkworm genotypes. The random ten cocoon filament weight registered on extra foliation of silkworm races were in descending order of PMXCSR2 (1.78 – 2.21g)> CSR2 (1.68 – 2.13g)> PM (1.02 – 1.38g). An increase in filament length shown by botanicals for races are given in ascending order PMXCSR2 (*P. glabra*<*B. spectabilis*<*P. niruri*<*T. arjuna*<*A. vasica*)> CSR2 (*B. spectabilis*<*P. glabra*<*A. vasica*, <*T. arjuna*<*P. niruri*)> PM (*B. spectabilis*= *P. glabra*<*A. vasica*<*P. niruri*<*T. arjuna*). The results of increased filament length on experimented races with botanicals are summarized in Table20 and Graph20 below.

L. Denier:

Silk filament weight in grams (SFW) and is silk filament length in mts (SFL) and 9000 is a constant value i.e. SFW/SFL X 9000. The additives enriched silk from silkworm races with different weight and length was measured in ratios. The denier measured for races are in descending order of their ratio are given CSR2> PMXCSR2> PM. An increase in denier shown by botanicals for races are given in ascending order, CSR2 (P. niruri<A. vasica = T. arjuna<P. glabra<B. spectabilis)> PMXCSR2 (T. arjuna<A. vasica<P. niruri<P. glabra<B. spectabilis)> PM (B. spectabilis = P. glabra<A. vasica<P. niruri<T. arjuna). The results of increased denier on experimented races with botanicals are summarized in Table.21 and Graph.21 below.

Table.8 and Graph.8. An effect of plant extract on Single Cocoon weight (gm) of Silkworm *B. mori*.

PLANTS/ RACES	SINGLE COCOON WEIGHT (gm)		
	PMXCSR2	PM	CSR2
A. vasica	2.086±0.007	1.265±0.008	1.970±0.006
B. spectabilis	1.986±0.006	1.239±0.005	1.938±0.005
P. niruri	2.046±0.047	1.256±0.007	1.971±0.006
T. arjuna	2.054±0.006	1.239±0.005	1.965±0.003
P. glabra	1.981±0.005	1.237±0.009	1.946±0.007
Water control	2.035±0.043	1.241±0.003	1.940±0.003
Normal control	2.051±0.003	1.240±0.005	1.949±0.004

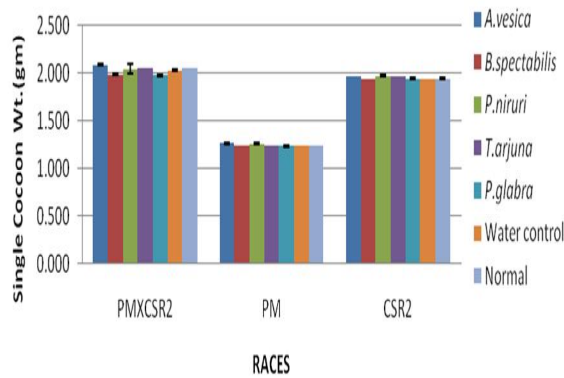


Table.9 and Graph.9. An effect of plant extract on Single Shell weight(gm) of Silkworm *B. mori.*

PLANTS/ RACES	SINGLE SHELL WEIGHT (gm)		
	PMXCSR2	PM	CSR2
A. vasica	0.393±0.006	0.206±0.008	0.367±0.004
B. spectabilis	0.380±0.003	0.192±0.003	0.339±0.004
P. niruri	0.395±0.006	0.213±0.005	0.373±0.005
T. arjuna	0.389±0.004	0.204±0.003	0.376±0.004
P. glabra	0.375±0.002	0.192±0.002	0.338±0.005
Water control	0.371±0.004	0.203±0.008	0.338±0.002
Normal control	0.356±0.003	0.186±0.004	0.318±0.003

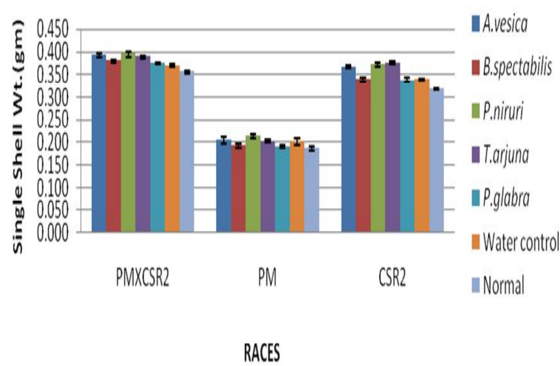


Table.10 and Graph.10. An effect of plant extract on Cocoon shell ratio% of Silkworm *B. mori.*

PLANTS/ RACES	COCOON SHELL RATIO %		
	PMXCSR2	PM	CSR2
A. vasica	18.84±0.22	16.25±0.50	18.64±0.15
B. spectabilis	19.15±0.10	15.52±0.22	17.47±0.16
P. niruri	19.31±0.15	16.98±0.27	18.92±0.27
T. arjuna	18.93±0.16	16.46±0.22	19.15±0.21
P. glabra	18.94±0.03	15.49±0.29	17.36±0.29
Water control	18.22±0.34	16.32±0.56	17.44±0.13
Normal control	17.37±0.15	15.03±0.34	16.33±0.10

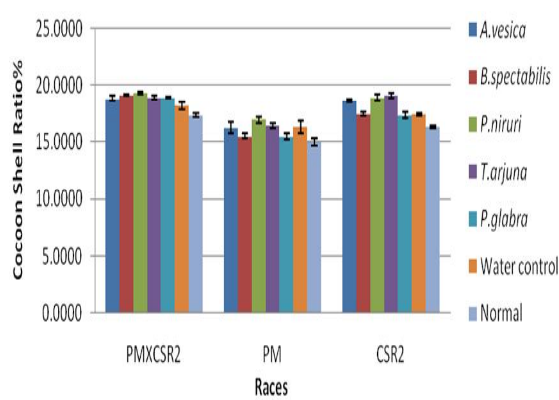


Table.11 and Graph.11. An effect of plant extract on Number of Cocoon per liter of Silkworm *B. mori*

PLANTS/ RACES	NUMBER OF COCOONS / Lit		
	PMXCSR2	PM	CSR2
A. vasica	83.33±0.58	110.33±0.58	82.33±0.58
B. spectabilis	88.67±0.58	116.33±1.15	87.67±0.58
P. niruri	81.67±0.58	109.33±0.58	81.33±0.58
T. arjuna	84.67±0.58	110.33±0.58	82.00±1.00
P. glabra	89.33±0.58	115.67±0.58	85.67±0.58
Water control	90.00±2.00	116.67±1.53	86.00±1.00
Normal control	97.00±1.00	122.00±1.00	90.00±1.00

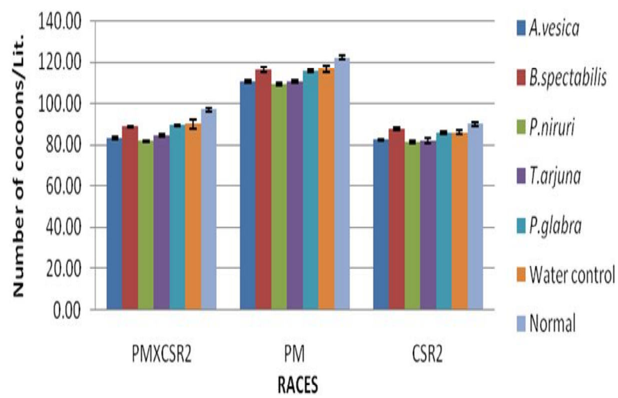


Table.12 and Graph.12. An effect of plant extract on Cocoon Length(cm) of Silkworm *B. mori*.

PLANTS/ RACES	COCOON SIZE LENGTH(cm)		
	PMXCSR2	PM	CSR2
A. vasica	3.35±0.05	3.87±0.03	3.52±0.03
B. spectabilis	3.38±0.03	3.68±0.03	3.47±0.03
P. niruri	3.22±0.08	3.87±0.03	3.50±0.05
T. arjuna	3.43±0.06	3.88±0.03	3.57±0.03
P. glabra	3.27±0.06	3.77±0.03	3.42±0.03
Water control	3.18±0.02	3.75±0.03	3.40±0.02
Normal control	3.08±0.08	3.50±0.05	3.23±0.03

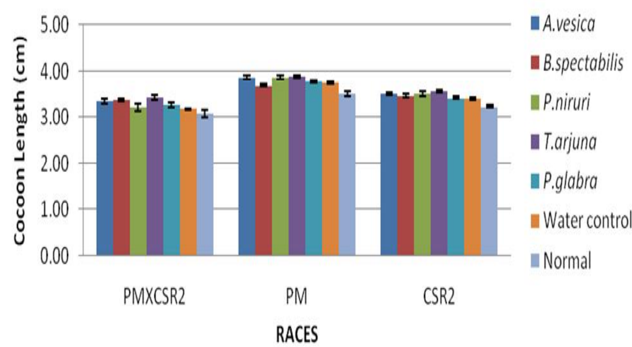


Table.13 and Graph.13. An effect of plant extract on Cocoon Breadth (cm) of Silkworm *B. mori*.

PLANTS/ RACES	COCOON BREADTH(cm)		
	PMXCSR2	PM	CSR2
A. vasica	2.25±0.05	2.07±0.03	2.28±0.03
B. spectabilis	2.12±0.03	1.78±0.03	2.28±0.03
P. niruri	2.27±0.03	1.97±0.03	2.35±0.05
T. arjuna	2.28±0.03	1.95±0.05	2.43±0.03
P. glabra	2.12±0.03	2.02±0.03	2.33±0.03
Water control	2.06±0.04	1.82±0.03	2.33±0.03
Normal control	1.92±0.03	1.73±0.03	2.14±0.04

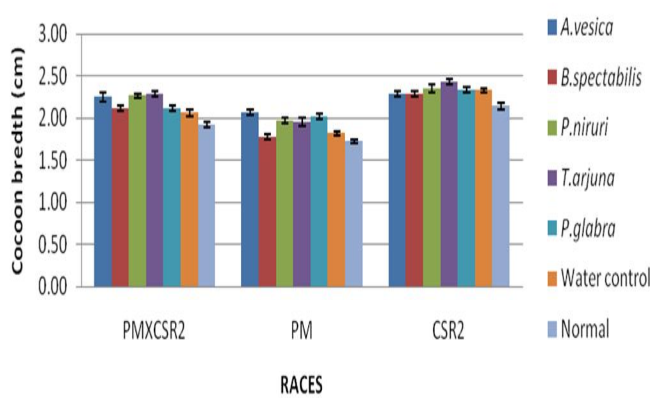


Table.14 and Graph.14. An effect of plant extract on Pupal Weight(gm) of Silkworm *B. mori*.

PLANTS/ RACES	PUPAL WEIGHT (gm)		
	PMXCSR2	PM	CSR2
A. vasica	1.693±0.003	1.059±0.002	1.603±0.004
B. spectabilis	1.605±0.003	1.046±0.003	1.600±0.004
P. niruri	1.651±0.041	1.042±0.002	1.598±0.009
T. arjuna	1.662±0.006	1.035±0.004	1.589±0.006
P. glabra	1.606±0.004	1.046±0.011	1.608±0.011
Water control	1.664±0.042	1.039±0.005	1.602±0.005
Normal control	1.695±0.006	1.053±0.008	1.631±0.002

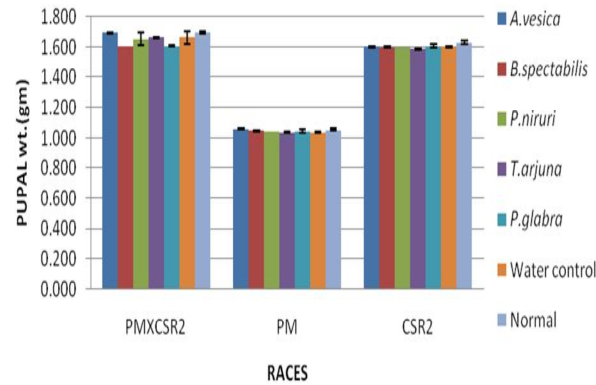


Table.15 and Graph.15. An effect of plant extract on Pupal Rate% of Silkworm *B. mori*.

PLANTS/ RACES	PUPAL RATE %		
	PMXCSR2	PM	CSR2
A. vasica	95.33±0.58	95.67±0.58	94.33±1.15
B. spectabilis	95.00±1.00	94.67±0.58	91.67±1.53
P. niruri	96.00±1.00	95.33±0.58	93.33±1.53
T. arjuna	96.33±0.58	95.67±0.58	94.00±1.73
P. glabra	96.33±0.58	94.33±0.58	95.00±1.00
Water control	94.00±1.00	91.33±1.53	93.00±1.00
Normal control	89.67±1.15	90.00±1.00	85.33±0.58

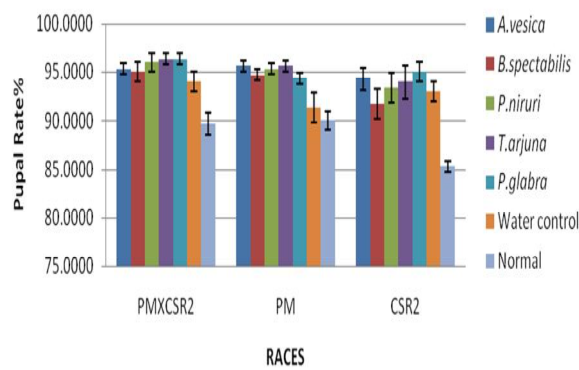


Table.16 and Graph.16. Effect of plant extract on No. of Cocoon yield per 10000 larvae of Silkworm *B. mori*.

PLANTS/ RACES	NUMBER COCOONS YIELD/10000 LARVAE		
	PMXCSR2	PM	CSR2
A. vasica	9633.33±57.74	9633.33±57.74	9566.67±57.74
B. spectabilis	9566.67±57.74	9533.33±152.75	9533.33±57.74
P. niruri	9733.33±57.74	9566.67±57.74	9633.33±115.47
T. arjuna	9666.67±57.74	9600.00±100.00	9500.00±100.00
P. glabra	9666.67±57.74	9566.67±57.74	9600.00±100.00
Water control	9500.00±100.00	9400.00±100.00	9366.67±152.75
Normal control	9300.00±100.00	9200.00±100.00	8900.00±100.00

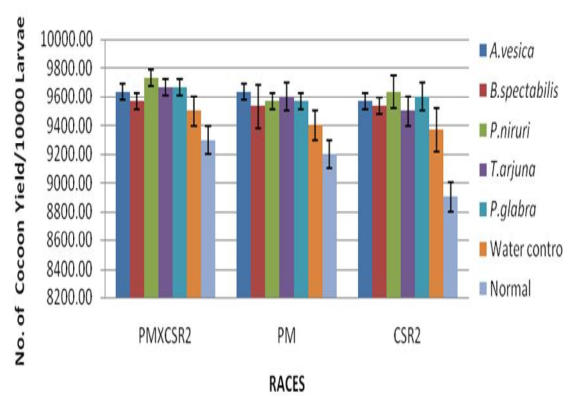


Table.17 and Graph.17 : Effect of plant extract on Weight of Cocoon yield per 10000 larvae of Silkworm *B. mori*.

PLANTS/ RACES	WEIGHT COCOONS YIELD/10000 LARVAE(k		
	PMXCSR2	PM	CSR2
A. vasica	20.10±0.10	12.17±0.06	18.80±0.10
B. spectabilis	18.97±0.15	11.80±0.20	18.43±0.15
P. niruri	19.93±0.47	11.90±0.10	18.93±0.21
T. arjuna	19.83±0.15	11.97±0.23	18.60±0.20
P. glabra	19.13±0.12	11.80±0.10	18.63±0.21
Water control	19.20±0.26	11.63±0.15	18.13±0.31
Normal control	18.97±0.15	11.37±0.12	17.30±0.20

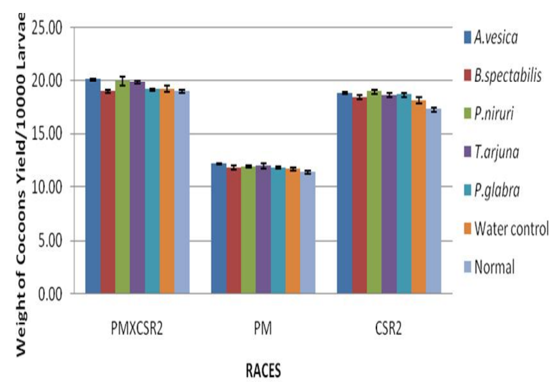


Table.18 and Graph.18. Effect of plant extract on filament Length(m) of Silkworm *B. mori*.

PLANTS/ RACES	FILAMENT LENGTH LENGTH(mt)		
	PMXCSR2	PM	CSR2
A. vasica	829.00±2.65	536.67±5.13	753.67±5.69
B. spectabilis	745.33±9.45	513.33±5.03	729.33±4.16
P. niruri	786.00±6.56	543.67±5.51	758.00±5.29
T. arjuna	822.67±10.02	552.00±9.54	756.00±4.58
P. glabra	745.00±7.55	514.00±6.24	734.33±10.97
Water control	741.33±7.02	516.33±6.03	719.33±7.02
Normal control	719.67±8.62	489.00±2.65	695.33±6.81

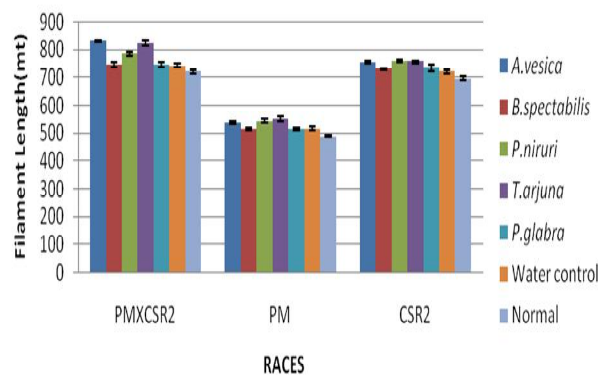


Table.19 and Graph.19. Effect of plant extract on Filament weight (gm) of Silkworm *B. mori.*

PLANTS/ RACES	FILAMENT WEIGHT (gm)		
	PMXCSR2	PM	CSR2
A. vasica	2.21±0.03	1.26±0.03	2.11±0.04
B. spectabilis	2.04±0.06	1.16±0.04	1.90±0.02
P. niruri	2.14±0.03	1.30±0.06	2.13±0.04
T. arjuna	2.18±0.04	1.38±0.06	2.12±0.02
P. glabra	2.03±0.03	1.16±0.04	1.91±0.06
Water control	1.98±0.11	1.17±0.04	1.82±0.04
Normal control	1.78±0.07	1.02±0.05	1.68±0.04

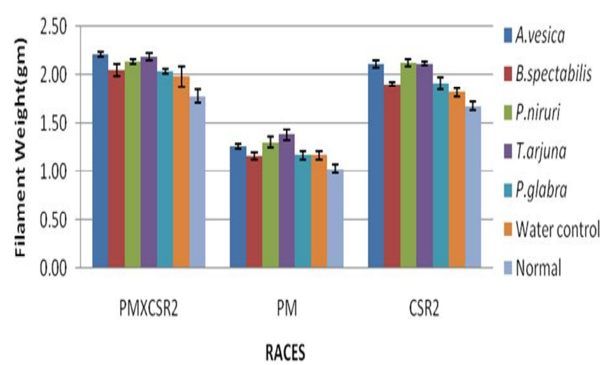


Table.20 and Graph.20. Effect of plant extract on Shell thickness(mm) of Silkworm *B. mori*.

PLANTS/ RACES	SHELL THICKNESS(mm)		
	PMXCSR2	PM	CSR2
A. vasica	0.47±0.01	0.32±0.02	0.42±0.02
B. spectabilis	0.41±0.01	0.30±0.01	0.39±0.02
P. niruri	0.45±0.01	0.33±0.02	0.42±0.02
T. arjuna	0.44±0.01	0.32±0.02	0.42±0.02
P. glabra	0.42±0.01	0.30±0.01	0.40±0.01
Water control	0.40±0.02	0.30±0.02	0.37±0.01
Normal control	0.36±0.02	0.26±0.02	0.32±0.02

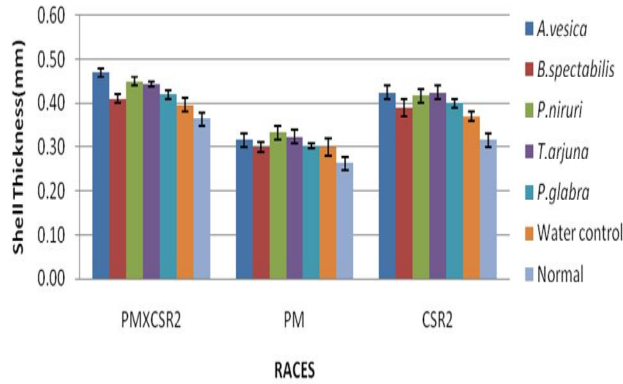
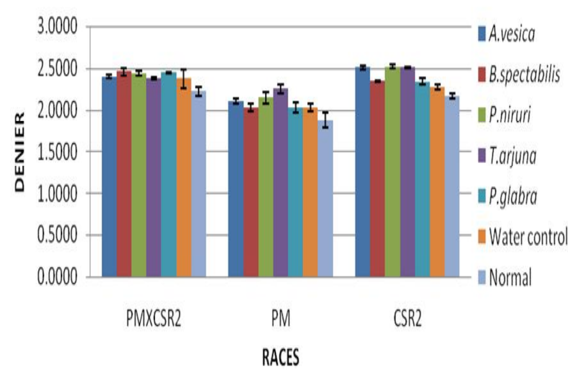


Table.21 and Graph.21. Effect of plant extract on Denier of Silkworm *B. mori*.

PLANTS/ RACES	DENIER		
	PMXCSR2	PM	CSR2
A. vasica	2.40±0.02	2.10±0.03	2.51±0.03
B. spectabilis	2.46±0.04	2.03±0.04	2.34±0.01
P. niruri	2.44±0.03	2.15±0.07	2.52±0.03
T. arjuna	2.38±0.01	2.25±0.05	2.51±0.01
P. glabra	2.45±0.01	2.03±0.06	2.33±0.04
Water control	2.38±0.11	2.03±0.05	2.27±0.03
Normal control	2.22±0.06	1.88±0.09	2.17±0.03



III. Field evaluation of effective plant extracts at farmers rearing houses.

The experimental data of "Selected botanical extracts on productivity on 5th instar silkworm larvae in diverse rearing parameters were found to be significant. The 3rd instar larvae obtained from KSSRDI observed to grow well in laboratory conditions till spinning so the maximum yield obtained 0.2ml and 0.25ml of *Adathoda vasica, Bougainvillea spectabilis, Terminalia arjuna, Phyllanthus niruri* and *Pongamia glabra* concentration of botanical extract was placed on to field trials. *B. mori* races PM, CSR2 and PMXCSR2 of larvae 4th and 5th instars were fed with these supplemented mulberry leaves. These botanical extracts on comparing with normal control and water control showed increase in field trials in following aspects *viz.,* cocoon weight, pupal weight, shell weight, Cocoon shell ratio, number of cocoons per liter, Cocoon size and breadth, Pupal weight, Cocoon yield in number, Cocoon yield in weight, Shell thickness, Filament length and breadth and Denier. The effect was high in respect to cocoon parameters in ex-situ conditions.

A. Single Cocoon Weight (G):

Among five tested botanicals *A. vasica, P. niruri* and *T. arjuna* increased cocoon weight of silkworm races PM, CSR2 and PMXCSR2 at varied degrees. The increased cocoon weight ratio of silkworm races after experimentation were as follows PMXCSR2>CSR2>PM. Among races PMXCSR2 showed progressive increase in cocoon weight on treatment with increased dosage of *A. vasica>T. arjuna> P. niruri* botanicals. CSR2 race cocoon weight increased respectively by botanicals of *P. niruri>A. vasica> T. arjuna*. PM race cocoon weight increase shown only with *A. vasica>P. niruri* botanicals. The cocoon weight of races PM, CSR2 and PMXCSR2 with supplements summarized in Table 24 and Graph24.

B. Cocoon shell ratio:

Economic parameters were analyzed among control and the field experimental silk worms. These results are in line with findings reported on cocoon shell ratio from different silkworms fed with extra-foliated mulberry leaves. The cocoon shell ratio of control treated silkworm was in range 15.03 to 16.32%. The cocoon shall ratio in treated groups was in range of 15.49% to 19.31% to about their increasing races of PMXCSR2 >CSR2> PM respectively. Silkworm race PMXCSR2 showed progressive increase in percentage of cocoon shell ratio on botanical extracts of *P. niruri* and *B. spectabilis*. CSR2 race cocoon shell ratio percentage has increased respectively by botanicals of *T. arjuna> P. niruri>A. vasica> B. spectabilis*. PM race increased cocoon shell ratio shown only with *P. niruri* and *T. arjuna* botanicals. A significant difference was observed among the various doses of botanicals on silkworm breed with respect to shell ratios are summarized in Table25 and Graph.25 below.

C. Cocoon yield/100 dfls (by number):

The cocoon yield by number per 10,000 larvae exhibited significant changes in each of silkworm genotype. The increasing trend in cocoon yield for 10,000 larvae were shown by races in descending order of PMXCSR2 >PM>CSR2 after being treated with botanicals. The effects on each race shown by different botanicals are as follows PMXCSR2 (*P. niruri*> *T. arjuna*>P. *glabra*> *A. vasica*> *B.* spectabilis), PM (*A. vasica*> *T. arjuna*> *P. niruri*> P. *glabra*> *B.* spectabilis) and CSR2(*P. niruri*>P. *glabra*> *A. vasica*> *B.* spectabilis> *T. arjuna*). The increase in cocoon formation by larvae after application of botanicals was found to be high and significant, due to decreased incidence of larval mortality. The results of experimented races with botanicals are summarized in Table.8 and Graph.8 below.

D. Filament length (m):

In field trials the filament length significantly increased in each silkworm breed after extra foliated V1 mulberry leaves were fed to breeds. The single cocoon filament length registered longest on extra foliation to races of silkworm were in descending order of PMXCSR2 (719.67 – 829.0 m)> CSR2 (695.33 – 758.0m)> PM (489.0 - 552.0mm). An increase in filament length shown by botanicals for races are given in ascending order PMXCSR2 (*P. glabra*=*B. spectabilis*<*P. niruri*<*T. arjuna*<*A. vasica*)> CSR2 (*B. spectabilis*<*P. glabra*<*A. vasica* <*T. arjuna*<*P. niruri*)> PM (*B. spectabilis*<*P. glabra*<*A. vasica*<*P. niruri*<*T. arjuna*). The results of increased filament length on experimented races with botanicals are summarized in Table.26 and Graph.26 below.

E. Denier:

Silk filament weight in grams (SFW) and is silk filament length in mts (SFL) and 9000 is a constant value i.e. SFW/SFL X 9000. The additives enriched silk from silkworm races with different weight and length was measured in ratios. The denier measured for races are in descending order of their ratio are given CSR2> PMXCSR2> PM. An increase in denier shown by botanicals for races are given in ascending order, CSR2 (P. niruri<A. vasica = T. arjuna<P. glabra<B. spectabilis)> PMXCSR2 (T. arjuna<A. vasica<P. niruri<P. glabra<B. spectabilis)> PM (B. spectabilis = P. glabra<A. vasica<P. niruri<T. arjuna). The results of increased denier on experimented races with botanicals are summarized in Table.27 and Graph.27 below.

Table.22 and Graph.22. An effect of plant extract on Fifth Instar Larval Weight (gm) of Silkworm *B. mori*

Plant extracts	FIFTH INSTAR LARVAL WEIGHT		
	PMxCSR2	PM	CSR2
A vasica	3.284±0.018	2.916±0.010	3.196±0.010
B spectabilis	3.163±0.021	2.812±0.023	3.169±0.008
P niruri	3.317±0.015	2.940±0.029	3.205±0.011
T arjuna	3.244±0.029	3.007±0.010	3.207±0.010
P glabra	3.122±0.003	2.871±0.016	3.153±0.008
Water Control	3.239±0.003	2.991±0.005	3.207±0.004
Control	3.251±0.002	2.848±0.002	3.176±0.004

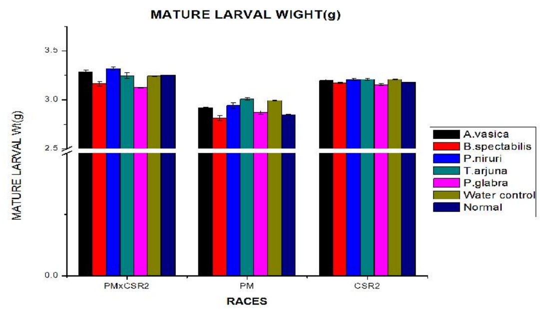


Table.23 and Graph.23 effect of plant extract on Fifth Instar Larval Duration (gm) of Silkworm *B. mori*

Plant extracts	FIFTH INSTAR LARVAL DURATION		
	PMxCSR2	PM	CSR2
A vasica	7.85±0.02	6.87±0.02	7.83±0.02
B spectabilis	7.86±0.03	6.80±0.02	7.86±0.02
P niruri	7.86±0.02	6.89±0.03	7.81±0.03
T arjuna	7.81±0.03	6.86±0.02	7.83±0.04
P glabra	7.78±0.06	6.80±0.04	7.84±0.05
Water Control	7.92±0.06	7.09±0.01	8.12±0.02
Control	8.13±0.01	7.12±0.02	8.13±0.01

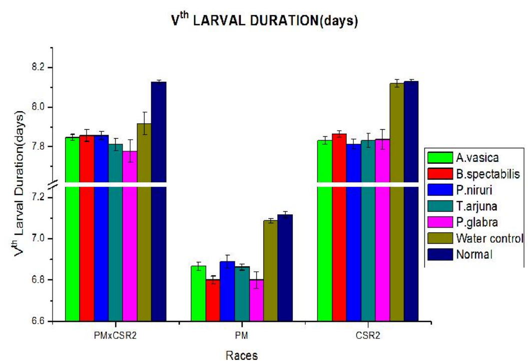


Table. 24 and Graph. 24 An effect of plant extract on Single Cocoon weight (gm) of Silkworm *B. mori*

Plant extracts	SINGLE COCOON WEIGHT (gm)		
	PMxCSR2	PM	CSR2
A vasica	1.877±0.006	1.139±0.006	1.773±0.007
B spectabilis	1.787±0.006	1.115±0.005	1.745±0.005
P niruri	1.842±0.016	1.130±0.005	1.774±0.006
T arjuna	1.849±0.006	1.115±0.005	1.769±0.005
P glabra	1.783±0.005	1.114±0.007	1.752±0.006
Water Control	1.831±0.039	1.117±0.004	1.746±0.004
Control	1.846±0.003	1.116±0.006	1.754±0.005

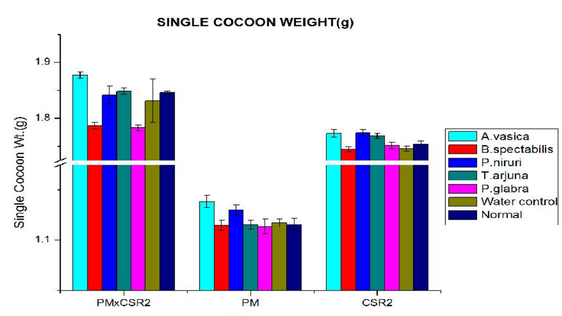


Table.25 and Graph.25 An effect of plant extract on Cocoon Shell Ratio % of Silkworm *B. mori*

Plant extracts	COCOON SHELL RATIO%		
	PMxCSR2	PM	CSR2
A vasica	18.67±0.15	16.58±0.25	16.84±0.13
B spectabilis	18.15±0.05	15.75±0.19	16.67±0.12
P niruri	19.33±0.14	16.33±0.22	17.93±0.20
T arjuna	18.33±0.16	15.67±0.18	18.67±0.19
P glabra	18.14±0.09	15.17±0.29	17.66±0.22
Water Control	17.42±0.24	15.32±0.31	16.44±0.27
Control	16.67±0.14	14.53±0.34	16.13±0.96

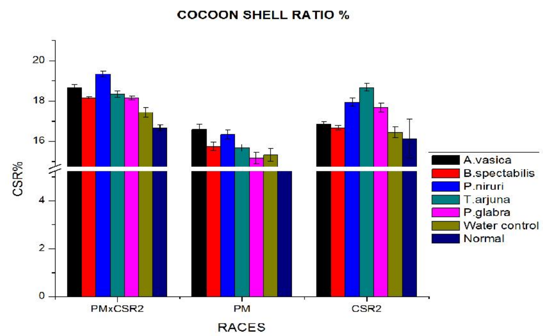


Table.26 and Graph.26 An effect of plant extract on Filament Length (m)of Silkworm *B. mori*

Plant extracts	FILAMENT LENGTH (m)		
	PMxCSR2	PM	CSR2
A vasica	746.1±4.68	483±4.60	678.3±4.62
B spectabilis	670.8±7.16	462±4.02	656.4±5.33
P niruri	707.4±4.74	489.3±4.56	682.2±4.27
T arjuna	740.4±6.67	496.8±7.94	680.4±5.83
P glabra	670.5±5.58	462.6±5.80	660.9±6.46
Water Control	667.2±4.69	464.7±6.03	647.4±5.77
Control	647.7±6.68	440.1±5.75	625.8±5.86

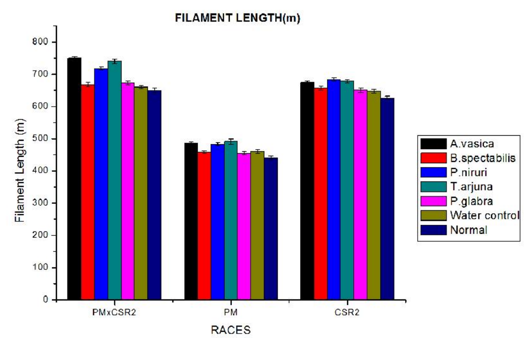
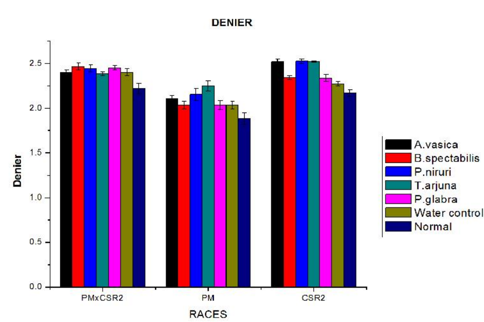


Table.27 and Graph.27 An effect of plant extract on Denier of Silkworm *B. mori*

Plant extracts	DENIER		
	PMxCSR2	PM	CSR2
A vasica	2.403±0.02	2.107±0.03	2.520±0.03
B spectabilis	2.467±0.04	2.034±0.04	2.345±0.02
P niruri	2.447±0.04	2.152±0.07	2.525±0.02
T arjuna	2.385±0.02	2.250±0.06	2.520±0.01
P glabra	2.452±0.02	2.037±0.05	2.337±0.04
Water Control	2.277±0.04	1.903±0.04	2.229±0.02
Control	2.222±0.06	1.883±0.07	2.170±0.04



DISCUSSION AND CONLUSION

The additive actions of botanicals reckoned from literature survey stimulated for experimentation of using botanicals (*Adathoda vasica, Bougainvillea spectabilis, Terminalia arjuna, Phyllanthus niruri* and *Pongamia glabra*) on races PM, CSR2 and PMXCSR2 of mulberry silkworm. The results obtained on conducting experiments have shown, emphasis of using these botanicals on silkworm traits for field application to support farmers in quantitative and qualitative silk production. The project encompasses on good knowledge about parameters viz., Single shell weight (g), Single cocoon weight (g), Cocoon shell ratio, Number of cocoons per liter, length and breadth, Cocoon size (Length X Breadth), Pupal weight, Cocoon yield/10,000 larvae (by number), Cocoon yield/10000 larvae (by weight), Shell thickness, Filament length (m), Filament weight) for obtaining high yields in controlled laboratory conditions. Nutrition plays an important role in improving the growth and development of *B. mori.*

High yields in quantity and quality of cocoons gave incites about healthy laboratory maintenance and good growing practices during experimentation. The experimental data on selected botanical extracts on productivity of 4th and 5th instar silkworm larvae presented using different rearing parameters found to be significant in production of high yields of silk by utilizing nutrition from mulberry and additives. The present study has found that botanical of concentration at 2% was highly effective. Good growth of 3rd instar larvae obtained from KSSRDI was due to hygienic laboratory conditions practiced. *B. mori* races of 4th and 5th moult PM, CSR2 and PMXCSR2 larvae were fed with 2% of *Adathoda vasica, Bougainvillea spectabilis, Terminalia arjuna, Phyllanthus niruri* and *Pongamia glabra* effect was so vivid with respect to cocoon yield due to enriched nutrient supply and digestion of mulberry leaves. The increased cocoon quality and quantity depended on various parameters such as complete nutrition obtained, anti-disease activity, compatibility with primary food, supplementing beneficial nosocomial bacteria of silkworm, increasing digestive flora and capacity of silkworm, reduction in free radicals formation of host etc…

A. vasica, P. niruri and *T. arjuna* fortification on PM, CSR2 and PMXCSR2 among five tested botanicals showed highest increase in single cocoon weight races at varied degree. The absorption of nutrient and higher digestion process is seen in silkworms of hybrid PMXCSR2 with lesser in CSR2 and lowest in Pure Mysore race. PMXCSR2 race increased its cocoon weight on treatment with *A. vasica*>*T. arjuna*> *P. niruri* botanicals. CSR2 race cocoon weight increased by botanicals of *P. niruri*>*A. vasica*> *T. arjuna*. PM race increased cocoon weight with *A. vasica*>*P. niruri* botanicals. The results of cocoon weight summarize that different races have different needs of supplementation. The highest productivity in race PMXCSR2 was is seen in relation to other two tested races of silkworm.

Administration of 2% aqueous leaf extract on fourth and fifth instar larvae of PMxCSR2, CSR2 and PM showed increased shell weight. The application of botanicals increased shell weight (length and breadth of the shell) due to better absorption of nutrients supplemented as botanicals on mulberry. The resulted increase in single shell weight to a maximum of 0.40g was seen due to the application, was found to be highly fruitful yield in vivo conditions. The field application in this line will be of great help for sericulture dependent population.

Cocoon shell ratio formula: CSR (%) = SW(g)/CW(g) X 100 [SW is shell weight in grams and CW is cocoon weight in grams]. The cocoon shell ratio from control to treated showed an approximate 3% increase especially in hybrid variety of PMXCSR2 on botanicals of (*P. niruri* and *B. spectabilis*), other two native varieties PM (*P. niruri* and *T. arjuna*) and CSR2 (*T. arjuna*> *P. niruri*>*A. vasica*> *B. spectabilis*) also showed high cocoon shell ratio indicating that experimented botanicals are highly effective in augmenting silk production through larvae.

Cocoon number per liter is a preliminary indicator for silk producing capability of silkworm races. The reduced cocoon number per liter will exhibit good silk yield. The decreased number of cocoons for race are PM (122-109/liter) were higher in comparison to CSR2 (90-81/liter) and PMXCSR2 (97-81/liter). This indicates PM has low cocoon size as well as cocoon length, such that filling increased number of cocoons in liter. The applicability of PM thus reduced in field conditions and increased compatibility of PMXCSR2 has greater production during application.

Cocoon size (Length X Breadth) in China and Japan have high length and breadth due to increased genetically variable hybrids, in contrast even though India has good hybrid varieties the length and breadth of the cocoon has not up to the exporting mark. The application of additive botanicals on feeding to silkworm can enhance the cocoon yield and meet the export quality demands yield extending silk to demanding export variety. The length and breadth of cocoons for race PM increased (0.38cm), CSR2 (0.34cm)> PMXCSR2 (0.35cm) and breadth CSR2 (0.29cm) and PMXCSR2 (0.36cm). These values indicate increase in length and breadth in PM, CSR2, PMXCSR2 races fortified with botanicals *B.* spectabilis, P. *glabra, A. vasica, P. niruri, T. arjuna.*

The pupal weight and silk of the yield are inversely proportional to each other. The Supplementation of plant extracts shows reduction in pupal weight of PMXCSR2 (0.9g), CSR2 (0.5g) and PM (0.02g). The additive effect of experimented plant extracts on pupal weight registered reduction in pupal weight in all races due to increased silk production.

Cocoon yield/10,000 larvae (by number and weight) were taken in an average for analyzing parameters like increase in weight and number of disease free cocoon production, increase in cocoon size and to obtaining moths. The recent experiments on ten thousand larvae have shown good quality of silk yield, and disease free moth for egg laying. The high yield of cocoon formation by larvae after application of botanicals was found to be significant on field also. The contributions of all experimented botanicals to shell thickness showed to be significant to various degrees. Silkworm race PMXCSR2 was found to have increase in shell thickness and in size compared to CSR2 and PM. Filament length (m) of extra foliated V1 mulberry leaves were fed to silkworm breeds. The filament length registered longest on experimented races of silkworm in comparison to control silkworm. An increase in filament length of PMXCSR2 (110m), CSR2 (93.0m) and PM (63.0 m) as exibited by tested botanicals. The race PMXCSR2 has high adoptability in comparison to other two experimented races. The increase in length of thread also increased its durability and variety of application in silk.

The increased filament weight augments tensile strength of silk fiber. A significant difference in filament weight was noticed between additive botanicals and control treated races. The ten cocoon filament weight registered on extra foliation of silkworm races showed PMXCSR2 (0.43g), CSR2 (0.45g) and PM (0.36g) increase. The increase in filament length showed by all experimented botanicals on all races augments for field trial and increase in farmers income.

Denier is value taken as SFW is silk filament weight (g) and SFL is silk filament length (m) and 9000 is a constant value i.e. SFW/SFL X 9000. The ratios of filament length and filament weight increased on treatment with botanicals, some of botanicals have shown equal effect on in races are as CSR2 (A. vasica = T. arjuna) and in PM (B. spectabilis = P. glabra).

Future line of work

The topical application of aqueous leaf extracts of plants has showed positive relationship with improvement in silkworm rearing and economic parameters. Most of the plant extracts have bio-chemical constituents which are alkaloids, glucosides, sterols and alcohols. These constituents having direct influence on growth and development of the silkworm in turn add to their physiological activities and act as phagostimulants helps in improving the rearing and economic parameters.

The plants could be commercially exploited for increasing cocoon production and also to reduce the disease incidence. Most of the plant extracts tested silkworm have very short shelf-life that could be increased by using proper adjuvants, which are going to serve as a tool to increase the efficiency of the same.

a. Identification and quantification of bio-chemicals responsible for phagostimulants in effective plant extracts is very much required.

b. Standardization of application methods for commercial silkworm rearing is very much essential.

c. As the plant extracts used in the experiment are natural, ecofriendly, biodegradable and also possesses insect growth promoting activity. Keeping this in view the limitation of plant extracts such as photodegradability, lack of suitable formulations and large scale field trails should be overcome.

d. Cocoon size (Length X Breadth) in China and Japan silk have high length and breadth of cocoon due to increased genetically variable hybrids, in contrast even though India has good hybrid varieties the length and breadth of the cocoon has not up to the exporting mark.

The cost benefit ratio should be worked out to know the beneficial effects of effective plant extracts before their commercial exploitation.

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